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From: Brent Erickson
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See attached

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Perspective

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A review of cellulosic biofuel commercial-scale projects in the United States

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Abstract: In contrast to a few years ago, when cellulosic ethanol via enzymatic hydrolysis was the only widely recognized technology for commercially producing cellulosic biofuels, a diversity of approaches are currently under commercial development. While no commercial-scale (≥20 million gallons per year) cellulosic biofuel facilities are operating at present, at least ten biorefinery projects employing six different pathways are expected to begin operations by 2014. These biorefineries will employ the following pathways: (i) catalytic pyrolysis and hydrotreating to hydrocarbons; (ii) gasification and Fischer-Tropsch synthesis to hydrocarbons; (iii) gasification and methanol-to-gasoline synthesis; (iv) dilute acid hydrolysis, fermentation to acetic acid, and chemical synthesis to ethanol; (v) enzymatic hydrolysis to ethanol; and (vi) consolidated bioprocessing (single-step enzyme production, hydrolysis, and fermentation) to ethanol. This review provides an overview of the six pathway technologies, comprehensive descriptions of each of the ten biorefinery projects, and a discussion of the current direction of cellulosic biofuel commercialization efforts and its implications for the revised Renewable Fuel Standard. © 2013 Society of Chemical Industry and John Wiley & Sons Ltd

Supporting information may be found in the online version of this article.

Keywords: cellulosic biofuels; commercialization; Renewable Fuel Standard; cellulosic ethanol; cellulosic hydrocarbons

Introduction

The revised Renewable Fuel Standard (RFS2) mandates the utilization of minimum volumes of biofuel in the US transportation fuel supply. Four separate yet nested biofuel categories are included in the mandate: total renewable fuel, advanced biofuel, cellulosic biofuel, and biomass-based diesel.[1] While the total renewable fuel, advanced biofuel, and biomass-based diesel category mandates have been met in part or in full since the RFS2's inception,[2] the cellulosic biofuel category has fallen well short of the mandate every year to present.[3] This category is limited to renewable fuels derived from cellulose, hemicellulose, or lignin feedstock that is originated from renewable biomass.[1] While the RFS2 originally mandated 100 million gallons of cellulosic biofuel in 2010, the Environmental Protection Agency (EPA) adjusted this down to 5 million gallons when it became clear that the

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original volume would not be met, although even that proved much higher than actual production.[4] A similar situation occurred in 2011 as obligated blenders under the RFS2 were penalized by the EPA for failing to blend non-existent cellulosic biofuels, despite a reduction in the mandated volume for that year from 250 million gallons to 9 million gallons.[5] This penalty has resulted in the filing of multiple lawsuits by obligated blenders against the EPA to prevent it from enforcing the cellulosic biofuels mandate in any year that the biofuels are not produced on a commercialscale.[6]

While the cellulosic biofuels mandate is at least three years behind schedule, several commercial-scale (defined here as plants with capacity greater than or equal to 20 million gallons per year) cellulosic biofuel facilities are currently under construction in the USA and expected to begin full operations by 2014. In contrast to a few years ago, when the federal government expected cellulosic ethanol produced via enzymatic hydrolysis to be the dominant advanced biofuels technology,[7] by 2014 a diversity of approaches for the production of cellulosic biofuels are likely to have been deployed. The nine commercial-scale facilities expected to be in operation by 2014 will employ six different cellulosic biofuel pathways. These pathways can be broadly categorized according to output as 'hydrocarbon-based biofuel pathways' and 'cellulosic ethanol pathways'.

This paper reviews six cellulosic biofuels pathways expected to be deployed as nine projects in the USA by 2014. It concludes with a discussion of the implications these facilities will have for the success of the cellulosic biofuels mandate under the RFS2 in the near future.

Pathways to cellulosic biofuels

Hydrocarbon-based biofuels via catalytic pyrolysis and hydrotreating

Fast pyrolysis is the rapid thermal decomposition of biomass feedstock in the absence of oxygen. The process produces a solid (char), a liquid (bio-oil), and a gas (non-condensable gases, or NCG). Raw bio-oil is a viscous and acidic mixture of organic compounds that can be upgraded to hydrocarbon-based fuels such as renewable gasoline and diesel fuel. One upgrading option is fluid catalytic cracking (FCC), in which bio-oil is deoxygenated and depolymerized[8,9] to hydrocarbons with varying boiling points that can be blended into hydrocarbon-based biofuels, such as renewable gasoline and diesel fuel. An alternative upgrading process is hydroprocessing, in which

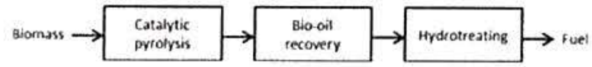

Figure 1. Catalytic pyrolysis and hydrotreating to hydrocarbons.

bio-oil is reacted with hydrogen to induce hydrodeoxygenation and depolymerization reactions for the same purpose. Bio-oil can be fractionated into carbohydrate-derived and lignin-derived components via a series of condensers and electrostatic precipitators for separate upgrading to optimize the process.[10]

Catalytic pyrolysis combines fast pyrolysis and FCC into a single integrated pathway by pyrolyzing the biomass feedstock in the presence of a zeolite catalyst. Catalytic pyrolysis produces a bio-oil with lower oxygen content than fast pyrolysis but at the cost of lower bio-oil yield and higher coke yield.[11] Bio-oil from catalytic pyrolysis must be further deoxygenated prior to conversion to gasoline or diesel fuel. While either FCC or hydroprocessing will suffice, at present the latter is receiving more attention due to its higher yields of liquids and the relatively low price of natural gas from which hydrogen is typically derived (Fig. 1). In theory, the hydroprocessing of catalytic pyrolysis bio-oil will consume less hydrogen than the hydroprocessing of fast pyrolysis bio-oil due to the former's lower oxygen content,[12] although there is currently little evidence for this in the literature.

Hydrocarbon-based biofuels via gasification and Fischer-Tropsch synthesis

Gasification of biomass yields a gas product containing carbon monoxide, hydrogen, methane, carbon dioxide, and lesser amounts of light hydrocarbons. This gaseous mixture, known as synthesis gas or syngas, can be reacted over catalysts or biocatalysts to produce liquid products suitable as transportation fuels. The integrated process of biomass gasification and biofuel synthesis is often referred to as biomass-to-liquids (BTL). Like fast pyrolysis and upgrading, this approach to biofuels has the advantage of converting all the components of the biomass into a fuel. Compared to acid or enzymatic hydrolysis of biomass, it also converts both carbohydrate and lignin into biofuels.

The best known of the BTL processes employs Fischer-Tropsch (F-T) synthesis, which occurs at high pressures in the presence of a metal catalyst to produce straight-chain alkanes (Fig. 2). The process is complicated by the presence of inorganic compounds in the gasification stream,

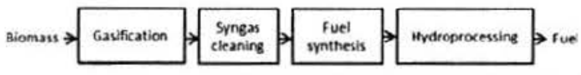

Figure 2. Gasification and Fischer-Tropsch synthesis to hydrocarbons. Adapted from Reference 10.

particularly sulfur and nitrogen, which quickly poison the metal catalysts even at low concentrations. Thus, extraordinary gas cleaning measures are required to produce an acceptable syngas for F-T synthesis, which represents a significant cost of fuel production.[13] The ratio of CO and H_2 must meet exacting standards for the catalyzed hydrogenation and hydrogenolysis processes to produce the desired alkanes. These alkanes can in turn be processed to gasoline, diesel fuel, and jet fuel.[8]

The primary disadvantages to the gasification and F-T synthesis pathway are its high capital costs. Biomass feedstock in particular contains a number of compounds that will poison the F-T synthesis catalyst if not almost completely removed from the syngas in an expensive cleaning process. F-T synthesis yields heavy hydrocarbon waxes that must be depolymerized via hydroprocessing into monomeric alkanes. The necessity of including equipment for both F-T synthesis and hydroprocessing despite the processes opposite purposes (repolymerization and depolymerization, respectively) also increases the pathway's capital costs relative to other biofuels pathways.

Hydrocarbon-based biofuels via gasification and methanol-to-gasoline synthesis

The methanol-to-gasoline (MTG) pathway was developed by ExxonMobil in the 1970s and first operated on a commercial-scale at a New Zealand facility using natural gas feedstock in the following decade.[14] More recently the pathway has been proposed as a route for converting biomass to renewable gasoline via gasification.[15]

As with the gasification and F-T synthesis pathway, biomass is gasified at high temperatures to produce raw syngas, which must be thoroughly scrubbed of impurities to prevent the inhibition of catalytic activity (Fig. 3). Steam reforming can be employed to adjust the ratio of H_2 and CO in the syngas to levels optimal for methanol synthesis. The resulting methanol is dehydrated over a catalyst to yield dimethyl ether (DME). Finally, the DME is reacted over a zeolite catalyst to yield olefins and ultimately a blend of aromatics and paraffins. The final hydrocarbon product is primarily in the gasoline boiling range, with the light gasoline and heavy gasoline fractions comprising 85 wt% of the product on a methanol basis.[15] The heavy gasoline fraction is reacted with hydrogen to meet fuel specifications. The remaining hydrocarbon product is used in the production of liquefied petroleum gas (LPG).

Cellulosic ethanol via dilute acid hydrolysis, fermentation to acetic acid, and chemical synthesis

Fermentable sugars (most prominently the monosaccharides glucose and xylose) can be derived from the lignocellulose that composes the cell walls of many plants.[16] Lignocellulose is a composite of cellulose polymers embedded in a cross-linked matrix of lignin and hemicellulose. Cellulose is similar to the polysaccharide starch except that β-glycosidic bonds instead of α-glycosidic bonds connect the glucose units. Hemicellulose is a polysaccharide comprised of branch-chained glucose, xylose, mannose, galactose, rhamnose, and arabinose units rather than just glucose units. Lignocellulose is highly resistant to both biological and chemical attack, partly due to its composite structure but also because of the highly crystalline nature of the cellulose. Lignocellulose must therefore undergo an extensive pretreatment to expose the cellulose and hemicellulose and separate the lignin, which cannot be fermented. Cellulose is more resistant to hydrolysis than starch, requiring extensive pretreatment to ensure its depolymerization into fermentable monosaccharides. The effectiveness of enzymatic hydrolysis in producing fermentable sugar from cellulose increases from as low as 20% of theoretical yield to as much as 90% when pretreatment is employed.[17] A number of pre-treatment steps are available, although dilute-acid, steam explosion, and ammonia fiber expansion (AFEX) are considered to be the most feasible.[18]

Dilute-acid hydrolysis employs H_2SO_4 (1 wt%) at elevated temperatures (100–220°C) to hydrolyze lignocellulose. Dilute acid hydrolysis yields are lower than for concentrated acid hydrolysis (55–60% of theoretical) as the use of higher temperatures causes oligosaccharide decomposition

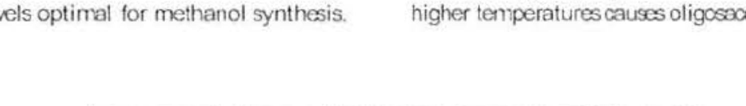

Figure 3. Gasification and methanol-to-gasoline synthesis.

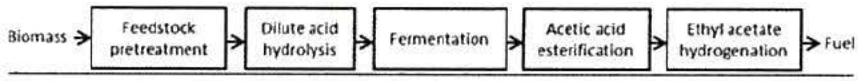

Figure 4. Cellulosic ethanol via dilute acid hydrolysis, fermentation, and chemical synthesis.

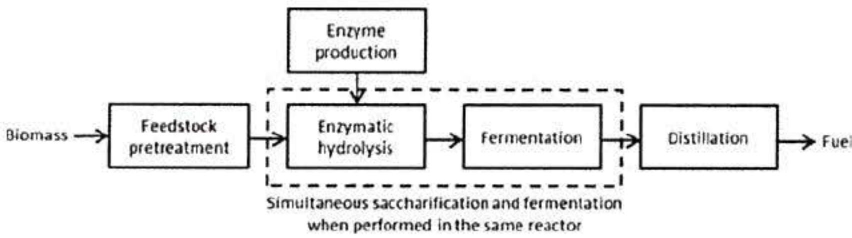

Figure 5. Cellulosic ethanol via enzymatic hydrolysis.

to compounds that inhibit microbial fermentation.[19] This yield reduction can be partially offset if hemicellulose is first removed via pre-treatment therefore minimizing the amount of sugar decomposition. Pre-treatment readily hydrolyzes hemicellulose, enabling this separation.

The C_5 and C_6 sugars liberated during dilute acid hydrolysis of cellulose and hemicellulose are fermentable by a number of microorganisms. While fermentation to ethanol is a possible route, one dilute acid hydrolysis pathway currently being considered for commercialization employs the acetogenic bacteria *Moorella thermoacetica* to ferment the sugars to acetic acid (Fig. 4).[20]

The acetic acid is converted to ethyl acetate via esterification:

$$CH_3CH_2OH + CH_3COOH \text{ ffi } CH_3COOCH_2CH_3 + H_2O \quad (1)$$

The ethyl acetate is then reacted with hydrogen in a final step to yield ethanol:

$$CH_3COOCH_2CH_3 + 2H_2 \text{ ffi } 2CH_3CH_2OH \quad (2)$$

Cellulosic ethanol via enzymatic hydrolysis

The enzymatic hydrolysis pathway employs cellulase enzymes instead of acid to depolymerize cellulose to glucose. Enzymes are purchased or produced in a separate bioreactor and added to the hydrolysis stage of this process. Separate hydrolysis and fermentation (SHF) can be employed, but high concentrations of glucose from the hydrolysis step can inhibit subsequent fermentation. To overcome this limitation and permit higher solids loading, hydrolysis and fermentation are sometimes combined in a single reactor in a process known as simultaneous saccharification and fermentation (SSF).[21] SSF has high specificity, which means that few unwanted products result.

In either case, the feedstock must first undergo size reduction and pre-treatment to maximize the accessibility of cellulose to the cellulases. No single enzyme is able to fully depolymerize cellulose, so enzymatic hydrolysis employs a system of cellulases.[22] The isoenzymes *cellobiohydrolase I* and *cellobiohydrolase II* hydrolyze cellulose to cellodextrin (oligosaccharide) and cellobiose (disaccharide). Cellodextrin is further hydrolyzed to cellobiose via the isoenzymes *endoglucanase I* and *endoglucanase II*. Finally, the cellobiose is hydrolyzed to monosaccharides via the enzyme *beta-glucosidase*. In principle, hemicelluloses can also be enzymatically hydrolyzed, but their more complex compositions means more kinds of enzymes are required than for cellulose hydrolysis.

Micro-organisms capable of fermenting both C_5 and C_6 sugars are added after hydrolysis (SHF) or simultaneous with the cellulases (SSF). Lignin acts as an anti-microbial agent and this can inhibit fermentation yields if specialized microorganisms are not used. Distillation occurs after fermentation to concentrate the resulting alcohol to fuel-grade ethanol (Fig. 5).

Cellulosic ethanol via consolidated bioprocessing

Consolidated bioprocessing (CBP) combines enzyme production, enzymatic hydrolysis, and fermentation into a single step for the production of cellulosic ethanol (Fig. 6).[23] This merger is made possible by

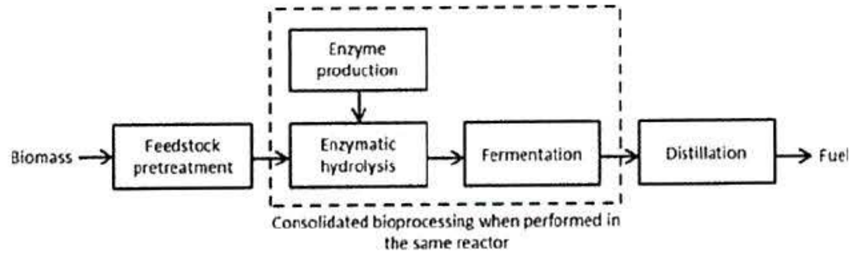

Figure 6. Cellulosic ethanol via consolidated bioprocessing.

micro-organisms capable of performing all three biological processes necessary for SSF. Consolidation of the unit operations for these three processes is expected to reduce capital and operating costs.[24]

The micro-organisms employed by CBP do not exist in nature and must therefore be genetically engineered. The two strategies currently under consideration for developing micro-organisms with the ability to both hydrolyze biomass and ferment the resulting sugars are classifi ed as the 'native strategy' and the 'recombinant strategy'.[24] The native strategy begins with micro-organisms that already are able to utilize cellulose, and focuses on engineering ethanol production into the microorganisms. The recombinant strategy begins with traditional ethanol producing microorganisms, and focuses on engineering the ability to produce enzymes capable of hydrolyzing biomass. While both strategies have yielded microorganisms capable of producing ethanol from lignocellulosic feedstock in laboratory conditions,[24] these have yet to be demonstrated under industrial conditions.

Pathway commercialization status

Hydrocarbon-based biofuels via catalytic pyrolysis and hydrotreating

KiOR is a Texas-based company that produces hydrocarbon-based biofuels from yellow pine via catalytic pyrolysis in the presence of either natural catalysts (clay) or synthetic zeolite catalysts followed by hydrotreating of the resulting bio-oil. The company plans construction of a 41 MGY facility in Natchez, MS, starting in the first quarter of 2013, with operations commencing by late 2014. Facility capacity is based on 1637 metric ton (MT) per day (1800 tons per day) feedstock consumption with expected initial fuel yield of 75 gal/MT feedstock.[25–27] The Natchez facility is estimated to cost $350 million. While the Natchez facility was originally expected to have a capacity of 34 MGY, the company announced in August 2012 that it was employing a new catalyst that decreased coke yields and increased facility capacity by 20%.[28] KiOR raised $150 million in a 2011 initial public offering[29] and has received loans and incentives from the state of Mississippi worth $81 million.[30] The company also voluntarily withdrew from the Department of Energy's (DOE) loan guarantee program in August 2011, which granted KiOR a $1 billion loan guarantee,[31] stating that it believed it could find loan terms comparable to those offered by the DOE program.[32]

Hydrocarbon-based biofuels via gasification and Fischer-Tropsch synthesis

ClearFuels Technology is a Hawaii-based subsidiary of synthetic fuels company Rentech that produces F-T liquids via the gasification of woody biomass. The company signed a memorandum of understanding with **Hughes Hardwood International** in February 2010 for the construction of a 20 MGY gasification and F-T synthesis facility in Collinwood, TN.[33] The facility is estimated to cost approximately $200 million.[34] The original plans called for groundbreaking in 2011 and commencement of operations by early 2014. **Rentech**, which purchased a majority equity stake in ClearFuels in April 2011, announced in November 2011 that construction of the Collinwood facility is on hold.[35] Rentech also stated that the decision on whether or not to proceed with the Collinwood facility would not be made until a demonstration-scale facility being built by Rentech in Commerce City, CO, was completed. Although the Commerce City facility was completed in December 2011,[36] no additional information on the Collinwood facility has been made public.

Hydrocarbon-based biofuels via gasification and methanol-to-gasoline synthesis

Sundrop Fuels is a Colorado-based company that produces hydrocarbon-based biofuels via the gasification of forestry residue followed by methanol-to-gasoline synthesis.[37] Sundrop recognizes that gasification of biomass will not produce syngas with sufficiently high H_2:CO ratio to synthesize hydrocarbon fuels. Rather than employ a catalytic water-gas shift reactor to produce higher H_2:CO ratios, as is typically done in gasification facilities, they plan to reform natural gas into hydrogen. They are exploring two distinctive approaches to hydrogen production: gasifying biomass in the presence of natural gas, oxygen, and steam, which reforms the natural gas within the gasifier, and autothermal reforming of natural gas in a separate reactor after which the syngas streams from the biomass gasifier and natural gas reformer are combined to achieve the desired H_2:CO ratio. This approach achieves higher carbon yields than traditional gasification-based approaches to biofuels.

Sundrop Fuels is building a $500 million facility in Alexandria, LA, for the production of up to 50 MGY of hydrocarbon-based fuels. Commercial operation is expected to begin in early 2014. The Alexandria facility is the first of several facilities that Sundrop Fuels plans to build to meet its goal of producing 1000 MGY of synthetic biofuels fuels by 2020. While Sundrop Fuels initially planned to use solar energy to power the project,[38] the Alexandria facility will be powered by NG so as to enable it to operate continuously.

The Alexandria project is receiving $14 million worth of performance-based incentives over 10 years from the state of Louisiana in addition to $4.5 million in the form of relocation reimbursement.[39] Sundrop Fuels is also applying for a $330 million private tax-free bond allocation designed by Louisiana to pay for the facility. The company also received a total of $175 million in outside investment, $155 million of which has come from Chesapeake Energy in exchange for a 50% stake in Sundrop Fuels.[40]

Cellulosic ethanol via dilute acid hydrolysis, fermentation to acetic acid, and chemical synthesis

ZeaChem is an Oregon-based company that produces ethanol via dilute acid hydrolysis and acetic acid synthesis of lignocellulosic biomass. The company is constructing a 25 MGY facility in Boardman, OR with an expected completion date of 2014.[41] Facility output will be evenly split between ethanol and bio-based chemicals such as acetic acid and ethyl acetate. The US Department of Agriculture (USDA) has awarded a conditional $233 million loan guarantee under its Biorefinery Assistance Program to ZeaChem for the Boardman facility, which is estimated to cost a total of $391 million;[42] the company has also raised $64 million in venture capital. A combination of agricultural residue and hybrid poplar will be employed as feedstock.

Cellulosic ethanol via enzymatic hydrolysis

Abengoa Bioenergy is a European ethanol producer that is building a commercial-scale cellulosic ethanol facility in Hugoton, KS. This facility will produce 25 million gallons of ethanol and 20 MW of electricity annually from corn stover via enzymatic hydrolysis.[43] Construction began on the facility in 2011 and it is targeted to commence operations in the last quarter of 2013.[44] The project, which is expected to cost at least $350 million, has received a $132 million loan guarantee from the DOE.

Beta Renewables is a joint venture between **Chemtex**, **TPG**, and **TPG Biotech** that is constructing a 20 MGY cellulosic ethanol via enzymatic hydrolysis facility in Sampson County, NC named Project Alpha.[45] Project Alpha, which is expected to commence operations in 2014, will employ as feedstock dedicated energy crops such as Arundo and switchgrass grown on cropland currently used to manage swine lagoon effluent.[45,46] The USDA has awarded the joint venture a $99 million loan guarantee under the Biorefinery Assistance Program for the $170 million facility, and a $3.9 million grant under its Biomass Crop Assistance Program for feedstock production.

DuPont Biofuel Solutions, a subsidiary of DuPont, has announced the construction of a commercial-scale cellulosic ethanol via enzymatic hydrolysis facility near Nevada, IA. The facility will be built for an estimated $276 million and will utilize corn stover as feedstock to produce 25 MGY of ethanol.[47] The facility has received a $9 million block grant from the Iowa Power Fund.[48] Unlike a number of other cellulosic biofuel companies, DuPont Biofuel Solutions is not seeking any loan guarantees from the federal government.[49]

POET, a major corn ethanol producer, and chemicals producer **DSM** have entered into a joint venture to produce cellulosic ethanol and license the technology to ethanol facilities both in the USA and globally.[50] The first phase of this process is construction of a 20 MGY facility in Emmetsburg, IA called *Project Liberty*, which will produce cellulosic ethanol from corn stover and cobs via enzymatic hydrolysis. The Emmetsburg facility has an expected completion date of 2013, with output increasing to 25 MGY by 2014.[51] Project Liberty is the first step in the joint venture's plan to produce 3500 MGY of cellulosic ethanol by 2022, 1000 MGY of which will come from adding cellulosic ethanol capacity to POET's 27 existing corn ethanol facilities. The facility is expected to cost $250 million and is covered by the joint venture. POET is rejecting a DOE loan guarantee for the project, stating that 'it has become unnecessary' due to the joint venture with DSM.[51] Project Liberty has received $20 million in funding from the state of Iowa.[52]

Cellulosic ethanol via consolidated bioprocessing

Mascoma is a cellulosic ethanol company that is constructing a 40 MGY cellulosic ethanol facility in Kinross, MI, as part of a joint venture with refiner **Valero**.[53] The project will use a single-step, 'consolidated bioprocessing' pathway to convert hardwood pulpwood feedstock into ethanol. The pathway combines enzyme production, enzymatic hydrolysis, and fermentation of the resulting sugars into a single step by genetically engineering micro-organisms to excrete enzymes that perform both the hydrolysis and fermentation into ethanol. The Kinross facility will cost $232 million and is expected to be completed by the end of 2013.[53] Mascoma has raised $115 million in venture financing[54] and $24 million in funding from the state of Michigan.[55] The company is also waiting for final approval for a loan guarantee from the DOE.[56] Finally, the company filed for a $100 million initial public offering in September 2011,[54] although the offering has not been completed as of the time of writing.

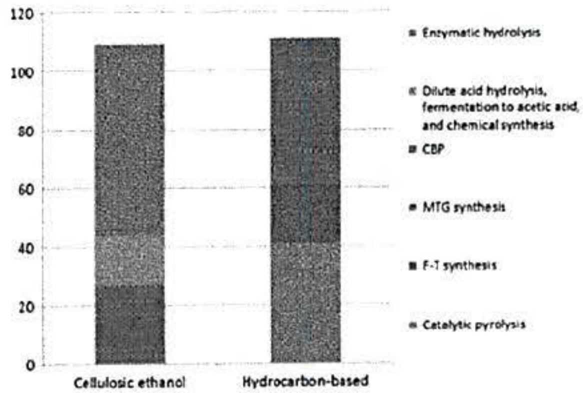

Figure 7. Expected cellulosic biofuel output by fuel category and pathway in 2014.

Discussion

Based on the commercial-scale cellulosic biofuel facilities that are currently expected to begin operations by 2014 (Table 1), total US cellulosic biofuel capacity in 2014 will be 266 MGY on a volumetric basis, or 215 million gallons on a gasoline-equivalent basis. This capacity will be roughly split between ethanol-based fuels and hydrocarbon-based fuels, with 111 million gallons of hydrocarbon-based fuels per year (52% of total) and 104 MGY of ethanol-based fuels on a gasoline-equivalent basis (48% of total) (Fig. 7). Cellulosic ethanol via enzymatic hydrolysis will represent the largest pathway in 2014 by volume (28% of total), followed by hydrocarbon-based

Table 1. Details of commercial-scale cellulosic biofuel projects expected to be in operation by 2014.

Company	Pathway	Location	Capacity (MGY)	Feedstock	Capital cost (million)
KiOR	Catalytic pyrolysis & hydrotreating to hydrocarbons	Natchez, MS	41	Yellow pine	$350
ClearFuels	Gasification & F-T synthesis to hydrocarbons	Collinwood, TN	20	Woody biomass	$200
Sundrop Fuels	Gasification & MTG synthesis	Alexandria, LA	50	Mixed biomass, natural gas	$500
ZeaChem	Dilute acid hydrolysis & acetic acid synthesis to ethanol	Boardman, OR	25	Agricultural residue, hybrid poplar	$391
Abengoa	Enzymatic hydrolysis to ethanol	Hugoton, KS	25	Corn stover	$350
Beta Renewables	Enzymatic hydrolysis to ethanol	Sampson County, NC	20	Arundo, switchgrass	$170
DuPont Biofuel Solutions	Enzymatic hydrolysis to ethanol	Nevada, IA	25	Corn stover	$276
POET	Enzymatic hydrolysis to ethanol	Emmetsburg, IA	20	Corn stover, corn cobs	$250
Mascoma	CBP to ethanol	Kinross, MI	40	Hardwood pulpwood	$232

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biofuels via gasification and MTG synthesis (23% of total), hydrocarbon-based biofuels via catalytic pyrolysis and hydrotreating (19% of total), cellulosic ethanol via consolidated bioprocessing (12% of total), hydrocarbon-based biofuels via gasification and F-T synthesis (9% of total), and cellulosic ethanol via dilute acid hydrolysis, fermentation to acetic acid, and chemical synthesis (8% of total). Of the nine planned facilities, four will employ enzymatic hydrolysis (44% of total), and the remaining five pathways will be employed by one facility apiece (11% of total).

Of possible importance to the future commercialization of cellulosic biofuel pathways is the notably larger capacity of the thermochemical facilities relative to the biochemical facilities. The average capacity of the six biochemical facilities detailed in this report is 17 million gallons gasoline-equivalent per year, whereas the average capacity of the three thermochemical facilities is 35 MGY, or 106% larger. A previous analysis calculated the optimal capacity of most thermochemical facilities to be substantially greater than biochemical facilities (fast pyrolysis was the notable exception).[57] While early cellulosic biofuel commercialization efforts appear to offer some support for this conclusion, the small sample size involved discourages reading too much into this.

Also of note is the prevalence of loan guarantee applications among the cellulosic biofuel projects detailed in this review. The companies behind seven of the nine projects have sought and/or been awarded large loan guarantees from either the DOE or the USDA. DuPont Biofuel Solutions and Sundrop Fuels are the exceptions, although both KiOR and POET have voluntarily withdrawn from the process. Abengoa Bioenergy, Beta Renewables, and ZeaChem have received loan guarantees from the federal government for a combined $464 million. State governments have also provided incentives, with Iowa, Louisiana, Michigan, and Mississippi contributing a total of $148 million in grants, loans, and incentives.

These initial commercial-scale facilities will play an outsized role in determining the future composition of the industry, as they will provide long-awaited data regarding the technical and economic feasibility of multiple cellulosic biofuel pathways on a commercial scale. The current plethora of advanced biofuels technologies is not expected to persist, as it is unlikely that they will all demonstrate comparable economical attractiveness.

The success or failure of these initial cellulosic biofuel facilities may determine the future of US government renewable energy policy. First, the widely publicized failures of the cellulosic biofuel mandate in 2010[4] and 2011[5] has generated skepticism about the industry's ability to meet the mandate during the lifetime of the RFS2, let alone in the near future.[58] Future failures to meet the cellulosic biofuels mandate even after drastic downward revisions by the EPA could jeopardize the mandate's continued existence. Second, the fact that almost half of the nine commercial-scale cellulosic biofuel facilities expected to be in operation by 2014 have either accepted or are pursuing loan guarantees from the US government places the costs of those facilities on the US taxpayer should any of them fail and, as the political fallout over the bankruptcy of US-backed solar panel company Solyndra demonstrated,[59,60] such failures can shine a harsh light on renewable policy and discourage future political support for the renewable energy industry.

DuPont, KiOR, POET, and Sundrop have publicly discussed building additional commercial-scale cellulosic biofuel facilities in the USA beyond 2014 should their initial projects prove successful, while companies including Genahol, Lanzatech, Rentech, and Virent have proposed building their first such facilities during the same time frame.[61] The success of these early projects would likely lead to a significant increase in capital investment within the cellulosic biofuels sector in the near-to-intermediate term. Their failure, on the other hand, could lead to a substantial shift in the direction of US alternative fuels policy. The recent adoption of new processes enabling the widespread extraction of shale gas has caused the domestic price of natural gas to fall sharply, and the US Energy Information Administration (EIA) forecasts it to remain low on a historical basis due to large domestic shale gas reserves. A continued lack of success by cellulosic biofuel producers could lead policymakers to instead pursue natural gas-based alternative fuels, whether in the form of compressed natural gas (CNG) vehicles or gas-to-liquid (GTL) pathways. In 2011 a bipartisan group of US representatives introduced legislation that would subsidize the use of natural gas-powered vehicles.[62] While the bill has been in subcommittee for more than a year, support for similar proposals is likely to grow if the cellulosic biofuels industry fails to prove its commercial-scale technical and economic feasibility in the next few years.

Conclusions

The first commercial-scale cellulosic biofuel facilities in the USA are expected to begin full operations in 2013, achieving 215 million gallons of annual production on a gasoline-equivalent basis by 2014. While this volume will place the cellulosic biofuel mandate of the RFS2 more than three years behind schedule (the unrevised mandate required 250 MGY

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of production in 2011), the production of commercial-scale volumes of cellulosic biofuel will represent an important and historical breakthrough for the cellulosic biofuels industry. Nine facilities with a capacity of 25 MGY or greater are expected to commence operations in 2013 and 2014. These facilities will employ six different pathways, with three pathways producing hydrocarbon-based biofuels (catalytic pyrolysis and hydrotreating; gasification and F-T synthesis; and gasification and MTG synthesis) and three producing cellulosic ethanol (dilute acid hydrolysis, fermentation to acetic acid, and chemical synthesis; enzymatic hydrolysis; and consolidated bioprocessing). Fifty-two percent of the expected capacity in 2014 will yield hydrocarbon-based biofuels and 48% will yield cellulosic ethanol. The success or failure of these initial facilities will affect both the future composition of the cellulosic biofuels industry and the future direction of US alternative fuels policy.

Supporting information

Supporting information may be found in the online version of this article.

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Robert Brown

Robert Brown is Anson Marston Distinguished Professor of Engineering and Gary and Donna Hoover Chair in Mechanical Engineering at Iowa State University (ISU). He is the founding director of ISU's Bioeconomy Institute. His research focuses on the thermochemical processing of biomass into energy, fuels, and chemicals.

Tristan Brown

Tristan Brown is a research associate in Iowa State University's Bioeconomy Institute. He is a licensed attorney and his research is directed toward the interplay between biorenewable pathways, economics and the law, particularly as they relate to the fields of tax law, international trade, and environmental policy.

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To: Argyropoulos, Paul[redacted]
From: Brent Erickson
Sent: Mon 3/25/2013 2:15:09 PM
Subject: cellulosic biofuels capacity are slated for completion by 2014.

The first wave of cellulosic biofuels projects are now reaching completion.

But what does the next wave look like – from technology to financing? We explore the trends in our two-part Biorefinery 2015 series.

It's a remarkable story of expansion. According to a report from Tristan R. Brown and Robert C. Brown at the Bioeconomy Institute at Iowa State University — 266 million gallons in cellulosic biofuels capacity are slated for completion by 2014.

Even more extraordinary? The $2.719 billion in project costs. A tribute to the companies themselves — and their backers — that they were able to raise the capital for first-of-kind technologies — through a combination of loan guarantees, capital from the public markets (in the case of KiOR) and capital from committed strategic investors and private owners.

Brent Erickson

Executive Vice President

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1201 Maryland Ave. S.W. , S. 900

Washington, D.C. 20024

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www.BIO.org/ind

*Follow me on **Twitter (@BErickson_BIO)***

To: Christopher Hessler (b) (6) [redacted]
Cc: Chris Miller (b) (6) [redacted]
From: Christopher Hessler
Sent: Fri 3/22/2013 9:20:05 PM
Subject: Chris Miller Joins AJW

Please see below for our announcement regarding Chris Miller joining our firm. We are pleased to have him on board, and I wanted to personally let you know about this recent development at AJW. I hope all is well with you.

Regards,

Chris

Christopher Hessler

Partner

AJW, Inc.

(b) (6) [redacted] (O)

(b) (6) [redacted] (M)

(b) (6) [redacted]

AJW's work focuses on enhancing market opportunities and removing market barriers for innovative technologies.

WASHINGTON, March 21, 2013 -- The public policy consulting firm AJW, Inc. has announced the addition of former Senate Democratic staffer Chris Miller to its growing business (www.ajw-inc.com).

"Chris brings a wealth of experience to the firm as we continue developing new ways to help innovative technologies overcome regulatory, political and market obstacles," says AJW founding Partner Chris Hessler. "He is an important addition to our team and gives us even more depth on the clean energy front."

Most recently, Miller was Senior Policy Advisor on Energy and Environment for U.S. Senate Majority Leader Harry Reid and the Senate Democratic Caucus, where he assisted on nearly all pieces of environmental and energy legislation considered in the Senate, including passage of the Energy Independence and Security Act of 2007.

At the Senate Committee on Environment and Public Works (EPW), Miller advised Chairman Jim Jeffords on environmental provisions of the Energy Policy Act of 2005 and handled climate change, Clean Air Act, and energy and environmental technology issues.

"AJW has a strong record of removing barriers to innovation," Miller says. "I look forward to helping create better opportunities for clean technology development and deployment, and addressing energy and environmental market failures and barriers that block companies' plans for sustainable growth."

Miller served on the Senate EPW Democratic staff at the same time AJW partners Hessler and Ted Michaels served on the EPW Republican staff.

AJW was founded in 2003 to meet the needs of technology innovators. It serves a wide array of nationally and internationally respected organizations including private corporations, non-profit organizations, business and industry organizations, foundations, research organizations and advocacy coalitions.

For media inquiries, contact:

Ted Michaels

Partner

For media inquiries, contact:

Ted Michaels

Partner

AJW, Inc.

[redacted]

[redacted]

AJW, Inc.

[redacted]

[redacted]

*********************** ATTACHMENT NOT DELIVERED *******************

This Email message contained an attachment named
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which may be a computer program. This attached computer program could contain a computer virus which could cause harm to EPA's computers, network, and data. The attachment has been deleted.

This was done to limit the distribution of computer viruses introduced into the EPA network. EPA is deleting all computer program attachments sent from the Internet into the agency via Email.

If the message sender is known and the attachment was legitimate, you should contact the sender and request that they rename the file name extension and resend the Email with the renamed attachment. After receiving the revised Email, containing the renamed attachment, you can rename the file extension to its correct name.

For further information, please contact the EPA Call Center at [redacted]. The TDD number is [redacted].

********************** ATTACHMENT NOT DELIVERED **********************

To: Argyropoulos, Paul [redacted] Weihrauch, John [redacted] Fitzgerald, Lindsay [redacted] Bunker, Byron [redacted] Manners, Mary [redacted]
From: Larry Schafer
Sent: Fri 3/22/2013 6:00:25 PM
Subject: Pretty good synopsis ---- E&E on hearing

E&E Daily: Small biodiesel producers still reeling as EPA sorts out fraud

Amanda Peterka, E&E reporter

Published: Wednesday, March 20, 2013

Small biodiesel companies continue to suffer from the lingering effects of three fraud cases in the fuel credit market despite U.S. EPA's efforts to clean up the mess.

Refiners are still hesitant to buy fuel credits from smaller producers, even from those that have had their production numbers audited and their credits certified. The lack of confidence in the market has forced independent biodiesel companies to sell their credits for discounts of up to 60 percent, market participants testified yesterday at an EPA hearing.

"Throughout the past 18 months I have done nothing but continue with the best business practices for my industry to no avail," said Jennifer Case, CEO of New Leaf Biofuel LLC, a 5-million-gallon biodiesel company in San Diego. "The market continues to discount my [credits] because of the fraud that was committed by a bad actor and because I am a small and mostly unknown company."

The issue of fraud has dogged small biodiesel producers since 2011, when EPA accused a company, Clean Green Fuel LLC, of producing millions of fake renewable identification numbers, the 38-digit figures attached to gallons of biodiesel. The credits are used by refiners to meet their yearly obligations under the renewable fuel standard.

Though the head of that company, Rodney Hailey of Maryland, has been sentenced to more than 12 years in prison and enforcement actions have been taken against two other companies found to be faking RINs (pronounced "rins"), the market continues to be rocky for small producers. Oil companies have spent millions of dollars on due diligence and prefer to buy their credits from larger, more name-brand producers.

Case said that her company has been examined at least five times in the past year by third-party auditors but that her credits are currently trading 10 to 12 percent lower than those from larger companies.

The fraud "has had a particularly devastating effect on the small biodiesel producers like New Leaf," Case said.

EPA has proposed creating a quality assurance program in which the agency would authorize third parties to conduct audits of producers. Refiners that purchase certified RINs would be able to claim an affirmative defense should those credits be found to be fraudulent.

The agency says it is eager to begin the program and provide certainty to the market (*Greenwire*, Feb. 11). It has proposed two types of quality assurance programs: Under the first, third parties would conduct audits continually and would be responsible for replacing invalid credits. Under the second, audits would be done quarterly, and refiners would be responsible for replacing RINs to meet their biodiesel obligations.

The proposal has been met with positive reactions overall, but producers, refiners and auditors at the hearing yesterday at EPA headquarters raised several issues that they hope to see fixed in the agency's final regulation.

Case said she worried that the smallest producers would be stuck with the largest burden because they would be forced to pay for the first, more expensive type of quality assurance program in order to engender enough confidence to be able to freely trade their credits.

"EPA needs to understand ... that the cost of compliance for small producers will be greater than all other biofuel producers and that although EPA calls the program voluntary, for small producers it is not voluntary," Case said. "It seems odd, unfair and perhaps punitive that the smallest of all the fuel companies are saddled with the highest required compliance costs."

She recommended that EPA require all refiners to annually purchase 15 percent of their credits under the more expensive option to spread compliance costs more evenly throughout the market. Case and several other witnesses also stressed the need for auditors to be truly independent from the market.

'Unnecessary cost, burden'

A representative from the ethanol industry, on the other hand, called the proposal too broad in scope because it would apply to all renewable fuels that have associated RINs -- not just biodiesel. The ethanol industry has not experienced fraud as the biodiesel industry has, largely because ethanol credits are assigned at the point of blending with gasoline and are never handled by producers themselves.

Over the past several years, 34.4 billion ethanol RINs have been generated, "and to our knowledge not a single one has been alleged or found to be fraudulent by EPA," said Geoff Cooper, an economist with the Renewable Fuels Association.

The quality assurance program could add "unnecessary cost and administrative burden to our members' operations," Cooper added. Though the program is voluntary in nature, Cooper said it seemed "inevitable" that obligated parties would require all credits to go through the program. Refiners are already signaling that they will only purchase certified credits.

"It's a little ironic that the program that was intended to improve liquidity in the relatively smaller biodiesel RIN pool may actually end up reducing liquidity in the [ethanol] RIN pool for renewable fuel producers who may not initially choose to participate," Cooper said.

The refining industry, which drafted the quality assurance program last year and then met several times with EPA officials to hash out details, yesterday said it also remained concerned with the expense and scope of the audits required under the program that the agency ultimately proposed.

"We are concerned that proposal goes too far with burdensome due diligence requirements," said Tim Hogan, director of motor fuels for American Fuel & Petrochemical Manufacturers.

Both Hogan and Patrick Kelly, a policy adviser at the American Petroleum Institute, also pushed EPA to relink credits and physical gallons of biodiesel, similar to the ethanol market. Producers, Kelly said, should be allowed to separate credits from gallons only if they are also refiners that have to comply with the renewable fuel standard.

"Eliminating this provision would have prevented the fraud experience thus far and would go a long way of preventing future instances of RIN fraud," Kelly said.

EPA has opened a public comment period on the quality assurance program and says it hopes to issue a final rule as soon as possible. The agency will not take enforcement actions this year against parties that use invalid 2013 credits that were verified before the release of the final rule. Any changes to the program will not go into effect until next year.

To: Argyropoulos, Paul[redacted]
From: [redacted]
Sent: Thur 3/21/2013 6:27:20 PM
Subject: RE: Link to RFA Letter - Enjoy

As always it was great to see you. Thanks for all you do.

Michael McAdams | **Holland & Knight**

President, ABFA
Sr Policy Advisor
800 17th Street, NW Suite 1100 | Washington DC 20006
Phone[redacted] | Fax[redacted]
michael.mcad[redacted]

Add to address book | View professional biography

From: Argyropoulos, Paul [mailto:[redacted]
Sent: Thursday, March 21, 2013 2:25 PM
To: McAdams, Michae[redacted])
Cc: McAdams, Michael[redacted])
Subject: Link to RFA Letter - Enjoy

Tough RFA letter to EPA & DOE on "Big Oil" undermining E15….

http://ethanolrfa.3cdn.net/73cf5a117cc5c1c112_9fm6b98iw.pdf

Paul Argyropoulos

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Mobile: [redacted]

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Web: www.epa.gov

To: Argyropoulos, Paul[redacted]
From: Joe Jobe
Sent: Thur 3/21/2013 5:05:14 PM
Subject: If it was easy, anyone could do it

Paul,

It was good to see you this week and visit with you briefly. I know you must be frustrated with everything that is going on. I just wanted to send you a personal note of encouragement. You guys put in a lot of hard work that is mostly thankless and you get criticized by all sides. I know what that is like. Please know that the work you guys are doing is worth the frustration because it is important and it is making a difference. If it wasn't making a difference, there wouldn't be so much fuss and opposition to it. Hang in there man. It will get better.

Joe

To: Argyropoulos, Paul[redacted]
From: Brent Erickson
Sent: Mon 3/18/2013 3:41:39 PM
Subject: New study on cellulosic cost potential
bnef_cellulosic ethanol costs_18_03_2013.pdf

Paul,

Here is an executive summary (attached PDF) of the actual study that Paul Winters got. It may be useful

.

Brent Erickson

Executive Vice President

Industrial and Environmental Section

Biotechnology Industry Organization (BIO)

Wanted to flag FYI this new study from Bloomberg New Energy Finance on the potential for cellulosic costs to fall to parity with corn ethanol by 2016.

http://about.bnef.com/press-releases/cellulosic-ethanol-heads-for-cost-competitiveness-by-2016/

CELLULOSIC ETHANOL HEADS FOR COST-COMPETITIVENESS BY 2016

12 March 2013

London, 12 March 2013 – Ethanol manufactured from non-food "cellulosic" feedstock is on course to be cost competitive with corn-based ethanol by 2016, according to an industry survey conducted by research company Bloomberg New Energy Finance.

The survey collected data and predictions on the production costs of 11 leading players in the cellulosic ethanol industry. All use a technique, commonly called enzymatic hydrolysis, to break down and convert the complex sugars in non-food crop matter, and a fermentation stage to turn the results into ethanol. The results showed that in 2012, the cost of cellulosic ethanol production was $0.94 per litre, around 40% higher than the $0.67 per litre (1) cost of producing ethanol from corn, which dominates the US biofuel market and is competitive with US gasoline. By 2016, respondents thought the price of cellulosic ethanol would match that of corn-based ethanol (2).

Harry Boyle, lead biofuel analyst at Bloomberg New Energy Finance, said: "The cellulosic ethanol industry has something of a history of over-promising cost reductions and under-delivering. However, it may be dangerous to assume that it will not become competitive this decade. If our survey proves accurate, cellulosic ethanol will make meaningful inroads into the vehicle fuel market during the last years of this decade."

The survey found that the largest cost elements for producers in 2012 were project capital expenditure, feedstock and enzymes. The operating costs of the process have dropped significantly since 2008 due to leaps forward in the technology. For example, the enzyme cost for a litre of cellulosic ethanol has come down 72% between 2008 and 2012.

Improvements in running costs for cellulosic ethanol plants will turn the spotlight squarely onto capital costs, which survey respondents expected to make up fully 45% of the overall expense of manufacturing a litre of cellulosic ethanol by 2016 – with feedstock contributing a further 34%. Developers will have to find ways of reducing the initial outlay on the plant, and reducing risk to attract cheaper financing. Boyle said: "We expect therefore to see a shift in focus over the next five to 10 years – from technology enhancements to logistical planning – that in turn suggests the industry is maturing."

Globally, there are 14 enzymatic hydrolysis pilots; nine demonstration-stage undertakings; and 10 semi-commercial scale plants either announced, commissioned, or due online shortly. Five of the semi-commercial facilities are located in the US, but a swing towards Brazil is expected in the near future, with two announced there so far. Bloomberg New Energy Finance defines a semi-commercial facility as having capacity of 90m litres per year, requiring an initial outlay of approximately $290m. By 2016 the second and third tranche of plants will be reaching commissioning, with annual capacities ranging from 90 to 125m litres. The initial outlay per installed litre is expected to fall from the original $3, to $2, due to economies of scale and a reduction in over-engineering.

This report details improvements in all the main stages of the cellulosic ethanol production process including pre-treatment, enzymatic hydrolysis and fermentation. The improvement in sugar release is reviewed, as is the switch from chemical to physical pre-treatment, which is making a difference in sugar release. The report assesses capex figures for equipment prices, experience curves and required rates of return. It also includes a sensitivity analysis of potential improvements in the coming years, and how they could speed up or slow down the industry's route to profitability.

Journalists are welcome to request a copy of the Executive Summary of the report. They can do so by emailingjames.isola@cubitt.com.

(1) Assuming a 10% weighted average cost of capital (WACC)

(2) Brazilian sugarcane ethanol production costs are currently only a few cents per litre lower than those of corn ethanol. So cellulosic ethanol could approach competitiveness with sugar-based ethanol too, over coming years.

ABOUT BLOOMBERG NEW ENERGY FINANCE

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NEW ENERGY FINANCE

CELLULOSIC ETHANOL COSTS: SURVEYING AN INDUSTRY

18 March 2013

INTRODUCTION

This Research Note assesses technology improvements in the cellulosic ethanol production process over the past four years – focussing on the enzymatic hydrolysis pathway – and what the industry can expect to see before 2016.

Starting in April 2012, we sent a survey requiring key performance and operating cost data to more than 30 developers working with this technology. We ran this data through an in-house production cost model, aggregating and anonymising the results. The survey covers 2008, 2010, 2012, 2014 and 2016 and required filling out 73 data points (or lines) for each of the five years – totalling a maximum of 365 data points per participant. However, not all of the developers initially contacted were in a position to provide data. Those that did participate did not always provide all 365 data points. Overall, 11 key enzymatic hydrolysis players submitted 1,891 data points. From this point forward, we will refer to all the developers that provided data points exclusively as the 'survey participants'.

There are 14 pilot, nine demonstration-scale and 10 semi-commercial-scale plants – all either online or due in the next two years.

Enzymatic hydrolysis – a pathway using enzymes to make ethanol from lignocellulosic biomass – has been heralded for years as the next-generation biofuel (or cellulosic ethanol) technology most likely to start commercial-scale production first. The pathway's appeal is that it does not compete for feedstock with food, and it may have the potential to undercut current ethanol production methods.

Organisations like Abengoa, BP, Clariant, DuPont, Mossi & Ghisolfi, Petrobras, POET, Raizen and Shell have all invested in cellulosic ethanol development. The initial outlay on the first tranche of semi-commercial facilities, commissioned between 2012 and 2014, will top $1.3bn. However, a series of technology, capital and policy barriers has held back commercialisation in the past five years. Globally there are: 14 pilot, nine demonstration-scale and 10 semi-commercial-scale plants either commissioned or due online in the next two years.

Our industry survey sets out to understand the key cost drivers of this cellulosic ethanol pathway, and highlight the main production cost barriers facing developers and how they should change in the coming years.

In the second half of the report, we use the aggregated survey data to conduct some sensitivity analysis on the key variables, helping to assess which have the greatest potential to lower production costs and bring profitability in the next five years. There are some unrealistic production costs in the public domain at present, which appear to confuse today and tomorrow's results. We set out therefore to provide more clarity, by aggregating and analysing actual industry developers' data.

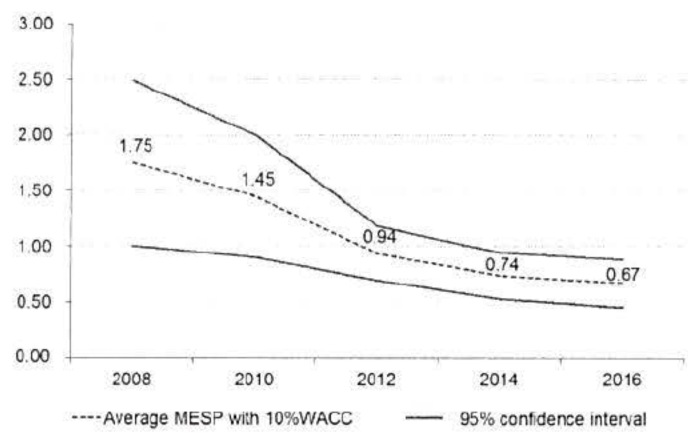
EXECUTIVE SUMMARY

This Research Note presents the aggregated results of a detailed industry survey carried out to understand the past, current and future cost drivers of cellulosic ethanol production. It analyses industry production costs from a global sample of demonstration and semi -commercial scale biorefineries, using data supplied by 11 operators and a Bloomberg New Energy Finance in -house cost model.

The report's ambition is to bring real operating cost data from today's technology developers into the public domain. The first half of the report presents aggregated and anonymised data from 11 leading technology suppliers. In the second half of the report Bloomberg New Energy Finance contextualises this data to uncover significant industry trends using s ensitivity analysis: it ascertains which variables are having the biggest cost impact, and examines if performance can reduce production costs beyond 2016.

- The minimum price at which cellulosic ethanol could be profitably sold, based on the semi - commercial enzymatic hydrolysis facilities coming online today, is \$0.94 per litre when accounting for a 10% weighted average cost of capital (WACC). This is an improvement of 46% on the laboratory and pilot scale cost s of \$1.75 per litre from 2008 . In 2016, when assuming the industry fully scales -up, the minimum ethanol sel ling price should drop to \$0.67 per litre – an 29% improvement on 2012 semi-commercial facility data.
  - The largest cost contributors to the minimal ethanol selling price (MESP) in 2012 were capital expenditure, feedstock and enzymes – accounting for 41%, 27% and 16% of these costs respectively.

Figure 1: Minimum ethanol selling price, 2008-16 (\$ per litre)



Source: Bloomberg New Energy Finance Notes: the 95% confidence interval represents the area in which 95% of the survey participants' MESPs fell into – or two standard deviations from the mean; the MESP includes capex costs at 10% WACC; and feedstock costs are fixed at \$75 per dry tonne.

- The maximum theoretical ethanol yield from a tonne of dry corn stover is approximately 427 litres. In 2008, yields were 58% of this maximum and 66% in 2012. These yield improvements have contributed 28% towards the reduction in MESP achieved since 2008.

- By 2016, we expect ethanol yields will surpass 75% of the theoretical maximum for corn stover, at about 328 litres per tonne. If this rate of improvement continues, yields should reach 96% of the theoretical maximum by 2025. Improvements in pretreatment sugar release, enzyme performance and fermentation microorganisms all directly influence ethanol yields.

- Enzymes are the most important technology component. In 2008, they contributed to 30% of total ethanol costs, or $0.53 per litre. By 2012 this figure had dropped to $0.15 per litre, or 16% of the total costs, representing a percentage improvement of 72%.
  - In the coming years, the rate of enzyme cost improvement is due to flatten out, reaching an enzyme cost contribution of $ 0.11 per litre in 2014 and $0.08 per litre by 2016. The lower cost of the enzyme cocktail per kilogram and the reduced amount of enzyme needed per tonne of biomass will drive these reductions though.
  - Our sensitivity analysis indicates increasing enzyme sugar release between 2008 and 2016 levels only improves the MESP by $0.02 per litre. The main cost reductions that enzymes bring therefore must come from: a reduction in their cost per kg; less enzyme loading; shorter residence time; and an increased tolerance to the solids in the biomass liquid.

- An initial outlay on a 90m litre semi-commercial plant will amount to about $270m. At a 10% WACC this translates to a capital cost contribution of $0.39 per litre, from the total $0.94 per litre ethanol production cost in 2012. By 2016, for a fully commercial facility, this cost should fall by 23% to $0.30 per litre from a total of $0.67 per litre.
  - Plant capital expenditure (capex) fell 34% between 2008 and 2012, as pilot plants were replaced by demonstration plants 100 times larger. The scale change between demonstration and semi-commercial plant size is less severe – a factor of 10. Once plants reach their full capacity towards the end of the decade, lower capex must come from more than just economies of scale. In 2016, capital expenditure will comprise 45% of the MESP with a 10% WACC.
  - The sensitivity analysis shows that reducing the weighted average cost of capital from 10% to 5% reduces the control case MESP by $0.12 per litre. However, for a first-of-a-kind plant the WACC is more likely to be over 15%, and increasing the WACC from 10% to 15% adds $0.15 per litre to the MESP.

- With the biomass price fixed at $75 per tonne, feedstock costs contributed 17% to the MESP in 2008. In 2016 they will comprise $0.23 per litre – or 34% of the total MESP. The feedstock cost contribution is therefore increasing as a proportion of the total, as other operating expense (opex) factors improve more quickly than ethanol yields per tonne of feedstock.
  - The sensitivity analysis shows reducing feedstock costs from $ 75 to $50 per tonne will lower the biomass expense by $0. 06 per litre. Meanwhile, the type of biomass also has an impact. High cellulose and hemicellulose contents – 38% and 26% respectively – can decrease the MESP by $0.05 per litre, from our control case.

- The data shows that developers are moving away from strong acid pretreatment to milder steam and acid pretreatment methods, leading to a decrease in both sugar release and biomass destruction. This reduces the opex, but also requires the enzymes to release more C5 sugars.

- If developers are able to secure feedstock and product off take agreements, validate their technology at a large enough scale, and prove a low plant initial outlay then they may be able to attract less expensive project finance. Retrofitting an existing first-generation ethanol facility, locating the project in a countr y with cheap construction costs and obtaining either generous green electricity and / or cellulosic ethanol subsidies, will all prove key factors.

- A careful study of a project's location and the existing infrastructure will greatly improve the MESP. The sensitivity analysis suggests that the MESP could fall by $0.23 per litre if plant feedstock costs are $50 per tonne, capex is restricted to $2 per litre of initial outlay through co-location and if it receives a green electricity price of $0.34 per kWh.
- In contrast, if all the technology variables – like pretreatment, hydrolysis and fermentation – are optimised, the MESP falls by only $0.10 per litre. We expect therefore to see a shift in focus ov er the next five to ten years, from technology enhancements to logistical planning, demonstrating how the industry is maturing.

ABOUT US

Subscription details

All Renewable Energy

[redacted]

Contact details

Harry Boyle Head of Bioenergy	[redacted] [redacted]
Claire Curry Analyst, Bioenergy	[redacted] [redacted]
Ulimmeh Ezekiel Analyst, Bioenergy	[redacted] [redacted]
Roberto Rodriguez Labastida Senior Analyst, Bioenergy	[redacted] [redacted]

To: Argyropoulos, Paul[Argyropoulos.[redacted]
From: Larry Schafer
Sent: Fri 3/15/2013 3:50:28 PM
Subject: You ok?

Larry Schafer

National Biodiesel Board

O: [redacted]

M: [redacted]

[redacted]

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1331 Pennsylvania Ave. NW

Suite 505

Washington DC 20004

To: Argyropoulos, Paul[Argyropoulos.[redacted]
From: Larry Schafer
Sent: Thur 3/14/2013 3:14:45 PM
Subject: A few questions ...

Paul,

Hope you are well ...

It's been an interesting week in the renewable fuels business ...

I have received the following questions and plan to answer them as follows. Can you let me know if my answers are adequate?

If calling would be easier .. then please call me at [redacted]

Thanks

========

Comment/Question: -THE RIN WEAKNESS WAS SAID TO BE TIED TO TWO MAIN FACTORS. AN ENERGY ANALYTICAL GROUP—SIMILAR TO INFORMA IN THE AG SPACE— **SUGGESTED THAT THE EPA COULD ALTER THE MANDATES AS EARLY AS THIS SUMMER. THE REPORT CITED THE UNSOLVABLE MANDATES FOR 2014 AND BEYOND AND SUGGESTED THERE WERE JUST NOT ENOUGH RINS TO COVER THE SHORTFALL.** WASHINGTON CONTACTS THOUGH INDICATED THAT WAS EXTREMELY UNLIKELY AND IF A CHANGE WERE TO HAPPEN IT WOULD BE IN LATE 2013 OR EARLY 2014 AND THEY HIGHLY DOUBT IT WILL OCCUR THEN

Any (real) chance of seeing reductions to any of the 2013 mandates

Larry's Comments: EPA does not have the authority to alter the mandates once they have been finalized unless they follow the waiver authority it has been given (and have previously executed twice already). Although we have an open rule to discuss the 2013 volume requirements for conventional, advanced and cellulosic. The conventional volume of 13.8 billion gallons is set by statute and EPA does not generally have the authority to change the number unless they go through the waiver process.

Comment/Question: PALM OIL STOCKS IN THE WORLD ARE EXPECTED TO REMAIN HEAVY AND WITH THAT THERE IS MORE EXPECTATION THAT PALM OIL IMPORTS TO THE U.S. WILL ACCELERATE AS SOYOIL TIGHTENS IN THE U.S. FOR MAY AND FORWARD.**THERE WAS EVEN TALK THAT ANOTHER TWO OR THREE PALM OIL MILLS HAD REQUESTED EPA APPROVAL TO BE IMPORTED TO THE U.S. AS PALM METHYL ESTER AND RECEIVE A RIN. THAT APPROVAL COULD COME AS SOON AS MIDJUNE.**

Could this prompt the EPA to relax/revisit its GHG calcs / feedstock requirements with an eye to 'approving Argentine SME or Malaysian/Indonesian PME for RIN Generation (either D4 and/or D6) or is this a dead end? Understand CARBIO, the argentine bio association is preparing responses to EPA's questions on the Arg Scheme, and thought they could get an answer by end of April.

Can plants be 'grandfathered' retroactively (as the second paragraph would seem to imply)? Or could this 'approval' refer to feedstock validation (and/or a resurrection of the PFAD discussion)?

Larry's Comments: EPA is currently reviewing the palm pathway. I do not know when it will be approved. Currently a grandfathered palm facility can generate a D6 RIN. I have been told that perhaps 1 or 2 palm facilities may be grandfathered, but I have no way of verifying that information.

On the question of grandfathered facilities – if a plant was in operation and producing biodiesel prior to Dec. 19, 2007 (or met the commenced construction requirements) then generally the facility could be registered by EPA as grandfathered so long as the registration materials was submitted by July 1, 2013.

I don't think EPA will relax GHG requirements or feedstock requirements – but certainly not without going through a notice and comment period ...

Larry Schafer

National Biodiesel Board

O: [redacted]

M: [redacted]

[redacted]

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To: Argyropoulos, Paul[redacted]
From: Edward Shipley
Sent: Thur 3/14/2013 4:34:18 AM
Subject: BIO 2013 discounts end today - register now and save

Early Bird Ends March 14!

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[redacted] (f)

To: Argyropoulos, Paul (b) (6) [redacted]
From: (b) (6) [redacted]
Sent: Wed 3/13/2013 2:11:59 PM
Subject: Lunch

Paul: You have time for lunch this week.

Michael McAdams | **Holland & Knight**
Sr Policy Advisor
800 17th Street, NW Suite 1100 | Washington DC 20006
Phone (b) (6) [redacted] | Fax (b) (6) [redacted]

Add to address book | View professional biography

To: Argyropoulos, Paul (b) (6) [redacted]
From: Brent Erickson
Sent: Tue 3/12/2013 5:44:19 PM
Subject: New Report on the Biobased Economy

Dear Paul,

I wanted to let you know that the **Milken Institute** just issued a new report called "**Unleashing the Bioeconomy** "on converting Ag feedstocks to renewable products and need for stable policy. Read the report here - www.milkeninstitute.org/pdf/BioEconFIL.pdf .

The United States' rapidly growing biobased economy is fueled by biotech companies leading an explosion of innovation as biorefineries across the country are producing new employment opportunities and jump-starting economic development when they're needed most. Industrial biotech is growing fast in Canada as well and more than $86-billion biobased economy already generates 7 percent of Canada's gross domestic product, according to Biotalk.ca.

Also recently **U.S. Secretary of Agriculture Tom Vilsack** wrote about the endless opportunities of advanced biofuels in particular to help grow the rural economy. "The production and use of advanced biofuels has already had a very positive impact for our nation, and biofuels hold even more opportunity to create jobs and economic prosperity for rural America in the years ahead," said Vilsack.

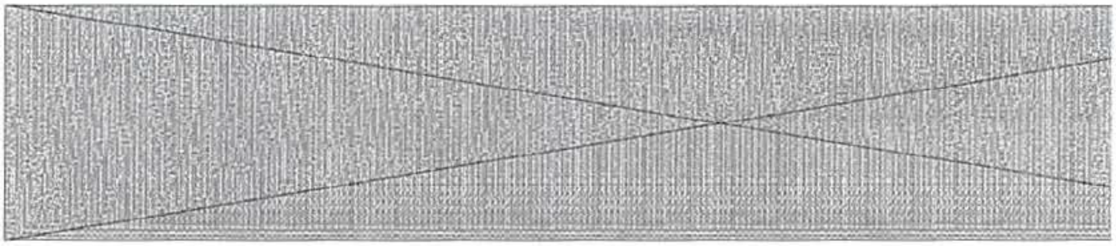
Environmental Entrepreneurs (E2) tracks growth of the advanced biofuel industry and their latest survey shows that more than 80 advanced biofuel businesses have started up in dozens of states across the country. According to a National Resources Defense Council (NRDC) blog post, 26 new biorefineries dedicated to making advanced biofuels will be open for business by 2015. The NRDC post says the new refineries alone will produce about 700 million gallons of clean, renewable, domestic fuel, and have the potential to create more than 18,000 jobs. According to the E2 survey, if state and the federal clean fuel standards are implemented as planned, 48,000 jobs could be created by 2015 throughout the entire advanced biofuel industry.

Advanced biofuels is slated to be a hot topic during both plenary programs and breakout sessions at the upcoming BIO World Congress on Industrial Biotechnology. The plenary sessions featuring advanced biofuels include a Monday afternoon plenary, ***Feeding Next Generation Biorefineries in 2013***, that will be comprised of biotech feedstock producers and experts in the field to discuss the progress in deploying conventional and novel feedstocks around the world, and what challenges feedstock providers face as they attempt to build and expand a marketplace for biobased raw materials.

The closing plenary, ***Feeling the Heat of the Biofuels Boom*** will include advanced biofuels producers, government officials, and biofuels customers will discuss significant policy challenges and mounting political pressure against the industry. Topics will cover the shift in public opinion on the potential for biofuels as a viable petroleum alternative, cap ex hurdles, regulatory burdens, and how the biofuels industry plans to overcome these obstacles in 2013. Learn more about BIO's World Congress on Industrial Biotechnology here.

Best Regards,

Brent Erickson
Executive Vice President
Industrial and Environmental Section
Biotechnology Industry Organization



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20[redacted] (f)

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To: Argyropoulos, Paul [redacted]
From: Wendy Siminski
Sent: Mon 3/11/2013 3:39:35 PM
Subject: 6 Week Countdown to BIO: Early bird rates end Thursday

Countdown to BIO: 6 Weeks

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...examines what's hot and happening right now in ...

...look.

...provided during registration, we'll give you a list to consider based on your interests.

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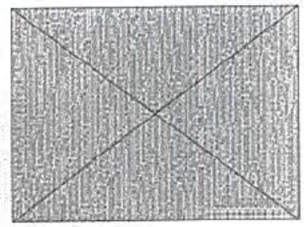
longer, register today and save up to 30%. Early bird rates end this Thursday, March 14.



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To: Argyropoulos, Paul[redacted]
From: Larry Schafer
Sent: Wed 2/27/2013 3:31:53 PM
Subject: Do you have a minute?

Larry Schafer

National Biodiesel Board

O: [redacted]

M: [redacted]

[redacted]

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Washington DC 20004

To: Argyropoulos, Paul (b) (6) [redacted]
From: Michael.McAda (b) (6) [redacted]
Sent: Tue 2/26/2013 7:42:02 PM
Subject: Delek

Paul; I forgot to ask, can you get someone to get me an update on Delek buying the biodiesel facility in Texas. They are eager to make some gallons. Thanks, see you tomorrow.

Michael McAdams | **Holland & Knight**
Sr Policy Advisor
800 17th Street, NW Suite 1100 | Washington DC 20006
[redacted]
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To: Argyropoulos, Paul[Argyropoulos.[redacted]
From: Brent Erickson
Sent: Tue 2/26/2013 3:48:25 PM
Subject: EIA cellulosics

Also note, EIA article on cellulosic biofuel potential for 2013-2015: http://www.eia.gov/todayinenergy/detail.cfm?id=10131

Brent Erickson

Executive Vice President

Industrial and Environmental Section

Biotechnology Industry Organization (BIO)

1201 Maryland Ave. S.W. , S. 900

Washington, D.C. 20024

PH [redacted]

www.BIO.org/ind

Follow me on ***Twitter (@BErickson_BIO)***

To: Argyropoulos, Paul (b) (6) [redacted]
From: Donnell Rehagen
Sent: Fri 2/15/2013 6:19:56 PM
Subject: National Biodiesel Conference & Expo - Presentation Access Credentials

February 15, 2013

Dear Paul,

Thank you for attending the 2013 National Biodiesel Conference and Expo! We hope you found your attendance to be beneficial.

Please participate in our conference survey which will be distributed electronically in the next several days so that you can help us continue to improve our conference. Also, please mark your calendars for the 2014 conference to be held January 20-23 in San Diego, CA. Please note the shift from our normal early-February dates to these dates in January.

Below is your login information if you which to access the presentations given at our conference. Simply, go to www.biodieselconference.org and use these credentials. You will find all of the presentations which we were given permission by the presenter to post located there. You will also find a list of conference attendees. Also, of note, there were a few presenters that did not utilize a visual presentation but, rather, offered their presentation verbally. For those, of course, you will not find posted presentations either.

Thank you again for your participation and we look forward to seeing you in San Diego!

Sincerely;

The National Biodiesel Board

Attendee Name: Paul Argyropoulos

Username:[redacted]

Password:[redacted]

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network, and data.  The attachment has been deleted.

This was done to limit the distribution of computer viruses introduced
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extension and resend the Email with the renamed attachment.  After
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rename the file extension to its correct name.

For further information, please contact the EPA Call Center at
[redacted]. The TDD number is [redacted].

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*********************** ATTACHMENT NOT DELIVERED *******************

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For further information, please contact the EPA Call Center at
(b) (6) [redacted]). The TDD number is (b) (6) [redacted].

*********************** ATTACHMENT NOT DELIVERED ***********************

To: Argyropoulos, Paul[redacted] Brooks, Phillip[redacted] Werner, Jacqueline[redacted] Belser, Evan[redacted] Kodish, Jeff[redacted] Simon, Karl[Simon.[redacted]
From: Larry Schafer
Sent: Tue 2/12/2013 2:36:36 PM
Subject: FW: OceanConnect filed for bankruptcy
TransportRoom.pdf

Fyi ...

Larry Schafer

National Biodiesel Board

O: [redacted]

M: [redacted]

[redacted]

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1331 Pennsylvania Ave. NW

Suite 505

Washington DC 20004

From: Franco, Sandra [mailto:[redacted]
Sent: Monday, February 11, 2013 11:43 AM
To: Larry Schafer
Cc: Franco, Sandra
Subject: OceanConnect filed for bankruptcy

Just as an FYI and in case you hadn't already heard, apparently OceanConnect filed for bankruptcy on

Friday. So the cases against them should be stayed under the rules of bankruptcy, which means they are likely not going to pursue their claims against EPA.

Print Less ---> Go Green

Sandra Franco
T [redacted]
F [redacted]
[redacted]

BINGHAM
Bingham McCutchen LLP
2020 K Street NW
Washington, DC 20006-1806

No. 12-20807

IN THE UNITED STATES COURT OF APPEALS
FOR THE FIFTH CIRCUIT

OCEANCONNECT, L.L.C.,

Defendant-Third Party Plaintiff - Appellant

v.

UNITED STATES OF AMERICA,
by and through the U.S. Environmental Protection Agency;
LISA P. JACKSON, in her official capacity as
Administrator of the U.S. Environmental Protection Agency,

Third Party Defendants - Appellees

Appeal from the United States District Court
for the Southern District of Texas, Houston Division
C.A. 4:11-CV-4311

OCEANCONNECT, LLC NOTICE OF BANKRUPTCY FILING AND AUTOMATIC STAY

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Attorneys for OceanConnect, LLC

COMES NOW, Keith B. Letourneau, attorney for Defendant OceanConnect, LLC, and would show the Court as follows:

1. OceanConnect, LLC filed for bankruptcy on February 8, 2013, in the United States Bankruptcy Court for the Southern District of New York. The case number is 13-22201.
2. The automatic stay provisions of Section 362 of the Bankruptcy Code are in effect.
3. All counsel of record are being notified of this action via notice of electronic filing.

Dated: February 8, 2013
Houston, Texas

Respectfully submitted,

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BELL, RYNIKER & LETOURNEAU

CERTIFICATE OF SERVICE

I certify that on this 8th day of February, 2013, I electronically filed the foregoing with the United States Court of Appeals for the Fifth Circuit via the Court's Electronic Filing System, and further certify that I have served, via the Court's electronic Case Filing System and by U.S. Regular Mail, the required copies of same on Appellee's counsel listed below:

Eric G. Hostetler
Environmental Defense Section
U.S. Department of Justice
P. O. Box 7611
Washington, DC 20044

Keith B. Letourneau